MISSOURI DEPARTMENT OF TRANSPORTATION
MATERIALS ENGINEERING
Jefferson City, Missouri

Test Method
MODOT T54
ASPHALT CEMENT CONTENT OF BITUMINOUS MIXTURES BY THE NUCLEAR METHOD

1.0 SCOPE.

1.1 This test method describes the quantitative determination of the asphalt cement content of bituminous mixtures by testing a sample with a device that utilizes neutron thermalization techniques. This method can be used for rapid determination of the asphalt cement content of bituminous paving mixtures. Testing can be completed quickly so that adjustments, if necessary, can be made in the asphalt cement metering system with a limited amount of mix production. This procedure is useful in the determination of asphalt cement content only

1.2 Unless the test sample is completely free of moisture, the percent moisture must be determined as described in Paragraph 8.6 of this test method and a correction made to compensate for the moisture.

2.0 APPARATUS.

2.1 Gauge, Model 3241-C manufactured by Troxler Electronic, Inc. with instruction manual.

2.2 Mixing Machine, Hobart A-200 with a 20 quart bowl or similar mixer with a wire whip mixing paddle (Central Laboratory).

2.3 Balance, capable of weighing to 15 kg, readable to 0.1 g (Central Laboratory).

2.4 Balance, capable of weighing to 12 kg, readable to 1 g (Field Laboratory).

2.5 Oven, capable of heating to 375 ± 5F (190 ± 3C).

2.6 Straightedge, steel, approximately 18 in. in length.

2.7 Plywood, 3/4 in. or thicker, or metal plate 3/8 in. or thicker having an area slightly larger than the sample pans.

2.8 Spoons, scoops, mixing bowls, trowel, and/or spatula.

2.9 High density polyethylene sheeting approximately 3/16" x 7" x 9". Size is not critical, however each size will produce specific readings. The readings should be within the intended working range of the gauge.

3.0 PRECAUTIONS.

3.1 Gauge operators shall have a valid Radiation Safety Training card in conformance with the Nuclear Regulatory Commission requirements 49CFR172, Subpart H in their possession.

3.2 Since the gauge equipment measures the total amount of hydrogen in the sample, this procedure is sensitive to changes in moisture content. It must be remembered that both asphalt cement and water contain hydrogen.

3.3 Keep any other source of neutron radiation at least 30 feet from the equipment. Do not use the equipment where large amounts of hydrogenous material may be moved during the calibration or testing procedures (for example, people, water, trucks loaded with bituminous mix, or plastic materials.) A change in the hydrogen background during testing may affect final test results.

3.4 The operator should be aware of changing conditions that could affect gauge results. Additional standardization testing should be performed, as described in Paragraph 4, if changes occur.

4.0 STANDARDIZATION.

4.1 Before operating a gauge in a new location, the surrounding conditions will be visually evaluated to determine if conditions are present which would affect the operation of the gauge. If visual evaluation is acceptable, proceed with the statistical stability and drift tests.

4.2 Statistical Stability & Drift Tests. The Statistical Stability (Stat) Test is performed for 1 minute intervals in accordance with Annex B. The Drift Test is performed in conjunction with the Stat Test. The tests are to be performed every 30 days during use and prior to using the gauge if 30 days have passed since the gauge was last used. Record all test results, passing or failing, and note any changes made in the surrounding environment or test conditions.

4.3 Background Test. A background test is to be performed at least daily prior to testing samples. The test period is to be 16 minutes. The gauge is to be left in the "power on" condition throughout the day. Record all background counts.

4.4 200 Count Stability Test. The count time for the 200 count stability test is to be 4 minutes. A 200 count stability test is to be performed in accordance with Annex A1 or Annex A2, as applicable, when necessary after repair of the gauge or to check stability in a

controlled environment.

5.0 LAB-TO-FIELD GAUGE CROSS CALIBRATION.

5.1 The transfer of a calibration from the laboratory gauge to the field gauge requires that a correlation between the gauges be established. This is accomplished by performing a cross calibration between the field gauge and the master gauge in the Central Laboratory. The Troxler's internal capability to correlate the gauges is to be used. This cross calibration is to be done semiannually, and the counting of samples in each gauge is to be within 24 hours of each other. Before beginning a cross calibration, the standardization procedures in Paragraph 4 are to be performed for each gauge. Record the results of the cross calibration.

5.2 Cross calibrations will be done with seven (7) samples. The seven samples will have asphalt cement contents of 3.0, 3.5, 4.2, 4.9, 5.6, 6.3, and 7.0 percent. The asphalt cement contents can vary ± 0.10 percent from the target content and are based on 100 percent mixture. The aggregates used will be from a mixture that was approved at not less than 6.0 percent asphalt content.

5.3 Cross calibration samples will be prepared in accordance with applicable parts of the paragraph on calibration sample preparation.

6.0 CALIBRATION SAMPLE PREPARATION.

6.1 A calibration will be performed by the Central Laboratory for each job-mix formula.

6.1.1 Materials for calibration samples are to be obtained in the same manner as trial mix materials for bituminous mixtures.

6.1.2 Samples for calibrating the gauge are to be prepared in a precise manner. The calibration is sensitive to the type of aggregate, percentage and source of asphalt cement, and aggregate gradation.

6.1.3 All aggregate will be separated into individual sieve fractions above the No. 8 sieve and recombined in the necessary quantities with the material passing the No. 8 sieve to meet the approved job-mix formula for which a calibration is being performed.

6.2 Three samples will be prepared for the calibration plus an initial batch to "butter" the mixture bowl and stirrers. This "butter" batch will be mixed at the low asphalt content point. The asphalt cement content of one sample will be the same as the job-mix formula, one will be 0.8 percent above and one 0.8 percent below the job-mix formula based on 100 percent mixture composition. These asphalt cement contents when calculated can vary ± 0.10 percentage point from the target content. The mixing order will be from lowest asphalt cement content to highest.

6.2.1 Each batch size will be as follows, unless additional material is needed to fill the

sample pan.

Limestone mixtures - 8,000 grams
Porphyry or Steel Slag mixtures - 10,000 grams

6.3 The prepared aggregate and bituminous material will be heated to a mixing temperature of 325 ± 5 F (163 ± 3 C) for wet mixing by the mechanical mixer.

6.4 Determine and record the tare weight (W_t) of the mixing bowl to the nearest 0.1 gram. When both aggregate and bituminous material are at the required mixing temperature and the mixing bowl is approximately the temperature of the aggregate, the aggregate is to be added to the mixing bowl and a weight determined (W_{at}) to the nearest 0.1 gram and recorded. The amount of asphalt cement to obtain the desired asphalt content will be added to the aggregate in the mixing bowl. The weight of the combined components and the bowl (W_{ct}) will be determined to the nearest 0.1 gram and recorded.

6.4.1 The weight of the aggregate (W_a) and the combined components (W_c) is to be determined as follows:

$$W_a = W_{at} - W_t$$

$$W_c = W_{ct} - W_t$$

6.5 The calculated percent asphalt content (% AC) of the prepared sample will be determined as follows and the result rounded to the nearest 0.01 percent.

$$\% AC = \frac{(W_c - W_a)}{W_c} \times 100$$

6.6 After determining the weight of the asphalt cement added to the mixing bowl, mix the sample for 2 minutes with the mechanical mixer.

6.7 After mixing, place the mixture into a batching pan. The sides of the bowl and stirrers are to be cleaned of mixture residue by scraping with a small limber spatula. The bowl and stirrers are not to be wiped with cloth or washed clean with solvent, except at the end of a calibration.

7.0 GAUGE CALIBRATION.

7.1 A calibration will be performed by the Central Laboratory for each bituminous mixture. Before the calibration is performed, the standardization procedures as described in Section 4 are to be performed. A calibration will be performed entirely in one gauge. That gauge serial number is to be recorded with the calibration results. All samples are to be mixed as specified in Section 6 and counted 16 minutes.

To begin a calibration, a test sample weight must be determined. The sample for the calibration with the lowest asphalt cement content is to be used to determine the test sample weight. Determine sample pan weight and record. Fill a clean sample pan one half full, then evenly distribute the sample in the pan with a trowel or spatula. Care should be taken not to exert pressure on the sample. Fill the remainder of the pan until the bituminous mixture in the pan is rounded slightly above the top of the pan. Level the top of the bituminous mixture using a spatula or trowel to an even head above the top lip of the pan. This head (approximately 1/2-in.) should be sufficient to create a condition that requires moderate effort to compress the sample into the sample pan. Use the metal or plywood plate to consolidate the bituminous mixture until it is even with the top of the pan. This should be done by placing the pan on the floor, placing the plate on top of the sample pan, and standing on the plate. Weigh and record the test sample weight (sample pan not included). This weight will be used for all calibration samples and all field or laboratory test samples using this calibration.

7.2.1 Prepare the remaining two samples at the test sample weight, ± 2 grams, as described above.

7.2.2 Each sample is then to be counted for 16 minutes in the master gauge.

7.2.3 The calibration curve is prepared by using the sample counts. The gauge will be used to develop this calibration curve. The percent asphalt cement content used will be based on 100 percent mixture. The curve will be a linear regression analysis of the gauge counts versus percent asphalt cement content. To be considered acceptable, a calibration should have a coefficient of correlation (Fit Coefficient) equal to or greater than 0.995.

7.2.4 The curve variables (A1 and A2), laboratory gauge background count, calibration sample weight, and the laboratory calibration gauge serial number will be transmitted to the field for use in the field gauges.

7.3 The calibration of a gauge with mixtures incorporating recycled asphalt pavement (RAP) presents special problems. The RAP must be of uniform gradation, asphalt cement content, and asphalt cement type. The RAP is to be mixed into the calibration samples in the same proportion as it will be used in the bituminous mixture. The calculated percent asphalt cement content used in the calibration will be the summation of added asphalt cement and asphalt cement content of RAP determined in accordance with AASHTO T 164, Method A.

8.0 FIELD TESTING.

8.1 The location of operation of a gauge is to be evaluated for acceptability using the standardization procedures described in Section 4.

8.2 The laboratory calibration values A1, A2, background count, and bituminous mixture test sample weight must be entered into the field gauge. When the gauge asks for a value of

A3, enter +0. The values of A1 and A2 for the transferred calibration may differ from the laboratory calibration values for A1 and A2.

8.3 Obtain samples of the freshly produced bituminous mixture in accordance with AASHTO T 168 or by sampling from a flowing stream discharge.

8.3.1 A sample from a flowing stream discharge is to be obtained at random in at least three approximately equal increments so that when combined there is a sample at least four times the sample size required for testing. Take each increment from the entire cross section of the material (stream) as it is being discharged. It may be necessary to have a special sampling device constructed for use at each particular plant. The sampling device should consist of a container of sufficient size to intercept the entire cross section of the discharge stream and hold that quantity of material without overflowing. A set of rails may be necessary to support the container as it is passed through the discharge stream. Samples obtained from stream discharge will be quartered as specified in AASHTO T 248, Section 9.1.1.

8.4 Preparation of field test mixture samples will be as follows:

8.4.1 Fill a clean, tarred, sample pan one half full, then evenly distribute the sample in the pan with a trowel or spatula. Care should be taken not to exert pressure on the sample. Fill the remainder of the pan until the test sample weight is achieved. Level the top of the bituminous mixture using a spatula or trowel to an even head above the top lip of the pan, approximately 1/2 inch. Use the metal or plywood plate to consolidate the bituminous mixture until it is even with the top of the pan. This should be done by placing the pan on the floor, placing the plate on top of the sample pan, and standing on the plate. The sample should be reweighed to determine if the test sample weight, not including sample pan weight, has been achieved. Variation from this weight of ± 10 grams is acceptable.

8.5 Samples are to be tested in the gauge for a time period of 16 minutes. Record the gauge counts and percent asphalt content. Precautions as described in Paragraph 3 are to be carefully followed.

8.6 The test sample must be checked for moisture content. If moisture is present, the percentage determined must be subtracted from the apparent asphalt cement percentage as indicated by the nuclear gauge counts.

8.6.1 The determination of moisture content may be made in accordance with AASHTO T 110, or MoDOT T53. These determinations may be done with a companion sample or with the test sample after testing in the nuclear gauge.

ANNEX A1

A1 Procedure for 200 Count Stability Test using Troxler Software Version 2.13. The software version may be verified during the initial RAM test.

A1.1 Move the gauge to an undisturbed location at least 30 feet from other neutron sources (For example: other asphalt content gauges). This test takes approximately 13 1/2 hours to complete.

A1.2 Turn the gauge on and allow it to run the RAM Test.

A1.3 At the prompt "SAMPLE DATA --- ERASE", press **NO**. Note: This prompt may or may not come on the screen. If the prompt does not come up, proceed with the next step.

A1.4 If the count time is something other than 4 minutes, change the count time to 4 minutes.

A1.5 Take a 4 minute background count, record and use.

A1.6 Place the polyethylene sheet in the chamber and close the chamber door.

A1.7 Activate the factory calibration.

A1.8 Press the following keys in the designated sequence **SHIFT**, **SPECIAL**, **.** and **0**.

A1.9 At the prompt "ALL SAMPLE DATA WILL BE LOST! DO YOU WANT TO CONTINUE?", press **"YES"**.

A1.10 At the prompt "SELECT: 1=STORE DATA, 2=DUMP DATA, 3=ERASE & EXIT", press **1** to store data while the 200 count stability test is being run.

A1.11 At the prompt "INPUT NUMBER OF PASSES (1-200)", input "200" and press **ENTER**.

A1.12 "PASS # 1 OF 200", should come up at the top of the screen with "TIME XXX SEC" at the bottom of the screen. This indicates the 200 count stability test has begun

A1.13 At the end of the test period, the screen display will show the mean and standard deviation for Percent Asphalt Cement, Raw Count 1, and Raw Count 2. Also Pass/Fail information will be displayed for either the Percent Asphalt Cement or Raw Count 1 and Raw Count 2. If the gauge passes the 200 count test, record the displayed information and proceed with step A1.14. If the gauge fails on one or both of the Raw Counts, record the displayed information and rerun the 200 count test. If the gauge fails on the Raw Count a second time, again record the information and contact the Central Laboratory. If the gauge fails on percent asphalt, record the displayed information and calculate the precision ratio for each Raw Count as follows: $PR = RSD / (RM)^{0.5}$

Where: PR = Precision Ratio

RSD = Raw Count Standard Deviation

RM = Raw Count Mean

If 0.902 =< PR =< 1.098 for both Raw Counts, the gauge is considered passing, otherwise calculate the precision limit in accordance with Annex A3.

A1.14 Press **ENTER**

A1.15 At the prompt "SELECT: 1=STORE DATA, 2=DUMP DATA, 3=ERASE & EXIT", select **3** (ERASE & EXIT)

A1.16 At the prompt "ARE YOU SURE, YOU WANT TO ERASE DATA", press **YES**.

A1.17 Gauge should come back to "GAUGE READY" display.

ANNEX A2

A2 Procedure for 200 Count Stability Test using Troxler Software Version 2.18. The software version may be verified during the initial RAM test.

A2.1 Move the gauge to an undisturbed location at least 30 feet from other neutron sources (For example: other asphalt content gauges). This test takes approximately 13 1/2 hours to complete.

A2.2 Turn the gauge on and allow it to run the RAM Test.

A2.3 At the prompt "SAMPLE DATA --- ERASE", press **NO**. Note: This prompt may or may not come on the screen. If the prompt does not come up, proceed with the next step.

A2.4 If the count time is something other than 4 minutes, change the count time to 4 minutes.

A2.5 Take a 4 minute background count, record and use.

A2.6 Place the polyethylene sheet in the chamber and close the chamber door.

A2.7 Activate the factory calibration.

A2.8 Press the following keys in the designated sequence: **SHIFT**, **SPECIAL**, **1**, **9**, **YES**, and **4**.

A2.9 At the prompt "ALL SAMPLE DATA WILL BE LOST! DO YOU WANT TO CONTINUE?", press **YES**.

A2.10 At the prompt "SELECT: 1=STORE DATA, 2=DUMP DATA, 3=ERASE & EXIT", press **1** to store data while the 200 count stability test is being run.

A2.11 At the prompt "INPUT NUMBER OF PASSES (1-200)", input **200** and press **ENTER**.

A2.12 "PASS # 1 OF 200", should come up at the top of the screen with "TIME XXX SEC" at the bottom of the screen. This indicates the 200 count stability test has begun

A2.13 At the end of the test period, the screen display will show the mean and standard deviation for Percent Asphalt Cement. Press **YES** and the screen display will show the mean and standard deviation for Raw Count 1, and Raw Count 2. Also Pass/Fail information will be displayed for either the Percent Asphalt Cement or Raw Count 1 and Raw Count 2. If the gauge passes the 200 count test, record the displayed information and proceed with step A2.14. If the gauge fails on one or both of the Raw Counts, record the displayed information and rerun the 200 count test. If the gauge fails on the Raw Count a second time, again record the information and contact the Central Laboratory. If the gauge fails on percent asphalt, record the displayed information and calculate the precision ratio for each Raw Count as follows: $PR = RSD / (RM)^{0.5}$

Where: PR = Precision Ratio

RSD = Raw Count Standard Deviation

RM = Raw Count Mean

If 0.902 =< PR =< 1.098 for both Raw Counts, the gauge is considered passing, otherwise calculate the precision limit in accordance with Annex A3.

A2.14 Press **ENTER**

A2.15 At the prompt "SELECT: 1=STORE DATA, 2=DUMP DATA, 3=ERASE & EXIT", select **3** (ERASE & EXIT)

A2.16 At the prompt "ARE YOU SURE, YOU WANT TO ERASE DATA", press **YES**.

A2.17 Gauge should come back to "GAUGE READY" display.

ANNEX A3

A3 Procedure For Calculating Precision Limit

A3.1 If the ambient temperature during the 200 count stability test changes more than 5ºF the gauge compares the percent asphalt data rather than the raw count data. Due to differences between actual background count and the factory background the comparison may be erroneously displayed as failing. This describes the procedure used to calculate a new precision limit.

A3.2 Given: Factory Calibration Background = 2200

A3.3 Given: Factory A(2) = 0.0030276

A3.4 Calculate mean gauge count:

$$MGC = (AC + 2.971852) / FA2$$

Where: MGC = Mean Gauge Count

AC = Percent Asphalt displayed at end of 200 count test.

FA2 = Factory A(2)

A3.5 Calculate gauge A(2):

$$GA2 = (FA2)(GBKG) / (FBKG)$$

Where: GA2 = Gauge A(2)

FA2 = Factory A(2)

GBKG = Gauge Background Count

FBKG = Factory Calibration Background Count

A3.6 Calculate actual gauge count:

$$AGC = MGC + (GBKG - FBKG)$$

Where: AGC = Actual Gauge Count

MGC = Mean Gauge Count

GBKG = Gauge Background Count

FBKG = Factory Calibration Background Count

A3.7 Calculate the new precision limit:

$$PL = (GA2)\ (AGC)^{0.5} / (PS)^{0.5}$$

Where: PL = Precision Limit

GA2 = Gauge A(2)

AGC = Actual Gauge Count

PS = Prescale

(PS=4 for 1 min. count, PS=16 for 4 min. count, PS=32 for 8 min. count, and PS=64 for 16 min. count.)

A3.8 Compare the calculated precision limit to the percent asphalt standard deviation displayed by the gauge. If the calculated precision limit is greater than the displayed standard deviation for percent asphalt, the gauge has passed the 200 count stability test. If the calculated precision limit is less than the standard deviation for percent asphalt, the gauge has failed the 200 count stability test and should be run a second time. If the gauge fails the 200 count stability test twice, contact the Central Laboratory.

ANNEX B

B1 Procedure for Statistical Stability (Stat) Test.

B1.1 With the gauge on and in the "Ready" position, press the yellow **SHIFT** key then the **9/SPECIAL** key.

B1.2 From the "SPECIAL FUNCTION" mode display, press **1** (Stat Test)

B1.3 Press **YES** at "STAT TEST…Time…Do you want to change?"

B1.4 Select **1** (1 min.) This will do 20, 1 minute counts.

B1.5 If you want to abort the Stat Test at this time, press **CE**.

B1.6 Close the door and press **START**.

B1.7 After the test has started, keep personnel and anything containing liquids at least 10 feet away from the gauge. Keep other radioactive material 30 feet away from the gauge.

B1.8 The gauge will beep at the end of each test.

B1.9 If the gauge shows "Failure", make sure no moisture source is within 10 feet or any other gauge has been moved into the area. Rerun the Stat Test. If the retest fails, contact the repair technician at (573) 751-5081 for further instruction.

B1.10 If the gauge shows "Pass" (acceptable limits for the Ratio are between 0.35 and 0.71), record the average counts (Avg. cnts) and the ratio (R).

B1.11 Press NO to return to the "Gauge Ready" display. "All data will be lost" may display but the data remains in the internal memory.

DO NOT TURN THE GAUGE OFF OR USE IT

WAIT 3 TO 4 HOURS, THEN RUN THE DRIFT TEST

Note: Before performing drift test, the environment should be the same as before the stat test was performed.

B2 Procedure for Drift Test.

B2.1 Press the yellow **SHIFT** key then the **9/SPECIAL** key.

B2.2 From the "SPECIAL FUNCTION" mode display, press **2** (Drift Test)

B2.3 Press **ENTER** at the "Drift Test" screen.

B2.4 The new screen should read “Will take five 4 min. counts.”, close the door and press **START**.

B2. 5 The gauge will beep at the end of each test.

B2.6 If the gauge shows “Failure”, make sure no moisture source is within 10 feet or any other radioactive gauges have been moved into the area. Rerun the Stat Test. If the retest fails, contact the repair technician at (573) 751-5081 for further instruction.

B2.7 If the gauge shows “Pass” (acceptable limit for the Drift is less than or equal to 1.6%), record the average counts (Avg. cnts) and the Drift %.

B2.8 Press **NO** to return to the “Gauge Ready” display.

B2.9 At this time, you can either continue to use the gauge or turn it **OFF**.